ESTHETICS AND SMILE CHARACTERISTICS FROM THE LAYPERSON’S PERSPECTIVE: A COMPUTER BASED SURVEY STUDY, PART II

A Thesis
Presented in Partial Fulfillment of the Requirements for
The Degree Master of Science in the
Graduate School of The Ohio State University

By
Richard W. Chan, B.S., D.D.S.

*****
The Ohio State University
2008

Master’s Examination Committee: Approved by
Dr. Henry Fields, Jr., Advisor
Dr. Michael Beck
Dr. William Johnston Advisor
Dr. Stephen Rosenstiel Graduate Program in Dentistry
ABSTRACT

Objectives: To quantify layperson’s ideal and maximum acceptable deviation for nine smile characteristics through digital technology. Methods: Photographs of ideal, symmetric dental configurations were digitally manipulated using Adobe® Photoshop® CS2. Incisor tooth proportions, central-lateral incisal edge lengths and gingival margins, maxillary central incisor width-length ratio and gingival margins, transverse occlusal cant, overbite, maxillary midline to face, and maxillary-mandibular midline were altered and placed in a female face, showing the lower portion of the nose to below the mentolabial fold. The composites of teeth and soft tissue were placed in random image sequences and imported into Quask™ Form Artist to generate the survey, which was administered in Columbus, OH (n=43); Seattle, WA (n=41) and Boston, MA (n=40), supported by power analysis. An interactive interface allowed raters to move a slider to adjust each variable to their choices. Rater reliability was assessed by rating every smile twice (26 images total). Results: Reliability ranged from $k=0.88$ to $0.47$. The smile became unattractive when the maxillary midline deviated 2.9mm or once the maxillary-mandibular midlines deviated 2.1mm. Overbite was ideal at 2.0mm and unacceptable at $<0.4$mm and $>5.7$mm. Central incisor crown width:height ratio was ideal at 0.73:1. The lateral incisor had an ideal lateral:central width ratio of 0.72:1, with a range of 0.53:1 to...
0.76:1. Maxillary central incisor gingival discrepancies were acceptable until >2.0mm. The ideal lateral incisor gingival margin was ideally 0.4mm incisal to the central. However, it was acceptable from 2.9mm incisal to 1.2mm gingival to the central gingival margin. The ideal central-lateral incisor step was 1.4mm and became unattractive >2.9mm. Transverse maxillary cants became unattractive at 4.0°. **Conclusions:** The range of acceptability for these smile characteristics remains large, and except for midlines, is equal to or greater than what most clinicians envision.
ACKNOWLEDGMENTS

I would like to thank my thesis committee, Dr. Henry Fields, Dr. Michael Beck, Dr. Stephen Rosenstiel, and Dr. William Johnston for their guidance and support. I feel blessed to have been able to work with such world-class researchers and people during this project. I would especially like to thank Dr. Fields for his patience and understanding throughout the past few years, and for his countless hours required to develop this unique and groundbreaking study.

I thank my classmates of the Class of 2008, Curtis Andrews, AJ Ker, Mike Rosvall, Brian St. Louis, and Beth Troy. I have enjoyed being a part of your lives. My time in residency at The Ohio State University will always be filled with the many great memories we have made during the last three years. I could not have asked for a better group of people with whom I could complete my orthodontic training. I will always cherish the friendships we have built with each other. I would like to specifically thank AJ Ker, who was the ideal partner for this project. It was a great pleasure working with you in creating, administering, and finishing this project.

I thank all the participants of the study, whose willingness to take the study allowed the data collection to go quickly and smoothly. I also thank the following orthodontists for the use of their time and office space during data collection: Dr. Mike
Fey, Dr. Kristina Grey, Dr. Tim Shields, Dr. Jackie Berkowitz, Dr. Frank Cordray, Dr. Stephen Hilzenrath, Dr. Sam Levine, and Dr. Daniel Varallo. Without their generosity I never would have finished this project.

I would like to thank my family for their tremendous love and support throughout the past many years. My days are always brightened when I see your faces. Your belief in me has given me the strength to reach my goals. Most importantly, I would like to thank my wife, Juli. Since we met ten years ago I have felt lucky every day to have you in my life. I thank you for the sacrifices you have made to allow me to finish my education. I am excited about spending the rest of our lives together.
Dedicated to my wife and children
VITA

March 21, 1976...................... Born, Logan, Utah

1994......................... Graduate of Kentridge High School
                           Kent, Washington

1995-1997...................... Missionary, The Church of Jesus Christ of Latter-
                              Day Saints
                              Taipei, Taiwan Mission

1994-2000...................... B.S.
                              Brigham Young University
                              Provo, Utah

2001-2005...................... D.D.S.
                              University of California, Los Angeles
                              School of Dentistry
                              Los Angeles, California

2005-2008...................... Graduate Resident in Orthodontics
                              The Ohio State University
                              Columbus, Ohio

FIELDS OF STUDY

Major Field: Dentistry

Specialty: Orthodontics
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Abstract</td>
<td>ii</td>
</tr>
<tr>
<td></td>
<td>Acknowledgement</td>
<td>iv</td>
</tr>
<tr>
<td></td>
<td>Dedication</td>
<td>vi</td>
</tr>
<tr>
<td></td>
<td>Vita</td>
<td>vii</td>
</tr>
<tr>
<td></td>
<td>List of Tables</td>
<td>ix</td>
</tr>
<tr>
<td></td>
<td>List of Figures</td>
<td>x</td>
</tr>
<tr>
<td>1.</td>
<td>Introduction and Comprehensive Literature Review</td>
<td>1</td>
</tr>
<tr>
<td>2.</td>
<td>Materials and Methods</td>
<td>18</td>
</tr>
<tr>
<td>3.</td>
<td>Manuscript: Esthetics and Smile Characteristics From the Layperson’s Perspective: A Computer Based Survey Study</td>
<td>31</td>
</tr>
<tr>
<td>4.</td>
<td>Conclusions</td>
<td>78</td>
</tr>
</tbody>
</table>

Bibliography: 79
### LIST OF TABLES

<table>
<thead>
<tr>
<th>Tables</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Logistic Variable Summary ........................................ 49</td>
</tr>
<tr>
<td>3.2</td>
<td>Weighted Kappa for Reliability ........................................ 51</td>
</tr>
<tr>
<td>3.3</td>
<td>Signed Rank for Torque Differences ........................................ 52</td>
</tr>
<tr>
<td>Figures</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------</td>
<td>------</td>
</tr>
<tr>
<td>3.1 Emoticon Example</td>
<td>53</td>
</tr>
<tr>
<td>3.2 Survey Slider Example</td>
<td>54</td>
</tr>
<tr>
<td>3.3 Smile Arc</td>
<td>55</td>
</tr>
<tr>
<td>3.4 Overbite</td>
<td>56</td>
</tr>
<tr>
<td>3.5 Lateral Step Up</td>
<td>57</td>
</tr>
<tr>
<td>3.6 Buccal Corridor</td>
<td>58</td>
</tr>
<tr>
<td>3.7a Canine Torque in a Broad Smile</td>
<td>59</td>
</tr>
<tr>
<td>3.7b Canine Torque in a Narrow Corridor</td>
<td>60</td>
</tr>
<tr>
<td>3.8a Posterior Torque in a Broad Smile</td>
<td>61</td>
</tr>
<tr>
<td>3.8b Posterior Torque in a Narrow Smile</td>
<td>62</td>
</tr>
<tr>
<td>3.9 Gingival Display</td>
<td>63</td>
</tr>
<tr>
<td>3.10 Central Gingival Display Height Discrepancy</td>
<td>64</td>
</tr>
<tr>
<td>3.11 Lateral Gingival Height Discrepancy</td>
<td>65</td>
</tr>
<tr>
<td>3.12 Crown Width to Height Ratio</td>
<td>66</td>
</tr>
<tr>
<td>3.13 Lateral Incisor Size</td>
<td>67</td>
</tr>
<tr>
<td>3.14 Maxillary Midline to Face</td>
<td>68</td>
</tr>
<tr>
<td>3.15 Maxillary to Mandibular Midline</td>
<td>69</td>
</tr>
<tr>
<td>3.16 Occlusal Cant</td>
<td>70</td>
</tr>
</tbody>
</table>
CHAPTER 1
INTRODUCTION

Esthetics has become a common term in dentistry. Dentists are now more obligated to understand harmony, beauty, proportion, and balance when planning treatment than ever before. Morley described a specific aspect of facial esthetics as macroesthetics, or the principles that apply when groupings of individual teeth are considered. He recognized the importance of understanding the relationship between those teeth and the surrounding soft tissue in the design of the smile. Laypeople have shown their opinion of the importance of the smile, when they ranked it second to only the eyes when reviewing features most important to facial esthetics. It is obvious that the smile is one of the most important facial expressions and is absolutely necessary in expressing different emotions, such as happiness, agreement, and appreciation.

The smile has been dissected throughout history. Most agree that the smile involves three main components – the teeth, the lips, and the gums. However, within these three components are many parts. Certain parts are more esthetically noticeable than others. More importantly, the smile can be very subjective. What is esthetic to one person can be nonesthetic to another. The subjective opinions of the smile to orthodontists, general dentists, and laypersons have been investigated in the past and
found to be different. Most previous scientific literature use photographs to show these components in their supposedly ideal and nonideal forms. To date, no studies have been published in the refereed literature in which individuals are allowed to use computer technology to actually manipulate smiles to make them most ideal and to define the thresholds of acceptability through a near continuous range of options.

COMPREHENSIVE LITERATURE REVIEW AND STATEMENT OF THE PROBLEM

Many authors emphasized the importance of the maxillary incisors during the evaluation of anterior dental esthetics. Development of a harmonious relationship between the central incisors and between central and lateral incisors was considered a hallmark of esthetic dental therapy. Brisman used adumbrations of the four maxillary incisors to establish that the width to length proportion of anterior teeth was ideally between 66 and 80%. Lombardi and Levin proposed that the proportion of visibility of a central and lateral incisor and of a lateral incisor and canine followed the golden proportion. That is to say that, on frontal view, 100% visibility of a central incisor is optimally paired with 62% visibility of a lateral incisor. Preston refuted this hypothesis. A web based study showed that dentists preferred a width to height ratio of 0.75-0.78 for the maxillary incisors, but what do lay people prefer? Recently, Wolfart and colleagues found the ideal width to length ratio and tooth to tooth proportions of
anterior teeth fell between 75 and 85% and 50 and 74%, respectively. But, the inclusion of medical students in their lay sample may have biased the outcome due to their increased knowledge of corporeal proportions. Additionally, their method of image modification did not limit the alteration to the teeth of interest. The limitations of previous studies and the variability in outcome warrant further investigation into preferences of tooth proportionality by lay people. In a survey of orthodontists, general dentists, and lay people, Kokich \textsuperscript{14} found that lay people needed a 2-mm deviation of the ideal crown length in order to classify the central incisors as noticeably less esthetic. In his research, Kokich defined the ideal central incisor crown width to height ratio at 0.77, and the 2-mm deviation resulted in a width to height ratio of approximately 0.90. In a study reviewing anatomic crown width/length ratios, Magne \textsuperscript{15} found that unworn central incisors had a ratio of 0.78. However, Magne’s study was performed on extracted teeth, and the length measurement was from the most incisal point of the anatomic crown to the most apical point of the CEJ. Therefore his width/length ratio may have been different than ratios found on teeth measured clinically in the mouth.

The lateral incisor is often noted as the anterior tooth that most frequently presents with anomaly of size and shape\textsuperscript{16}. The most frequent anomaly is a “peg” shaped tooth where the height is grossly increased in comparison to the width. Kokich changed the width of the maxillary incisor in 1.0 mm increments and found that the threshold for the layperson was 4.0 mm narrower than the ideal lateral incisor\textsuperscript{14}. In this study his ideal lateral width to central width ratio was approximately 0.78 while the threshold size (4.0 mm narrower) had a ratio of approximately 0.45.
Maxillary midline deviations can drastically upset the balance characteristic of esthetic smiles\textsuperscript{17-19}. The center of the philtrum\textsuperscript{2, 4, 20, 21} and nasion\textsuperscript{2, 21} have been commonly used to establish the soft tissue midline. Previous studies have shown that the maxillary midline may deviate in the transverse dimension and still be esthetically acceptable. While Frush\textsuperscript{22}, Johnston\textsuperscript{23}, Cardash et al\textsuperscript{24}, and Beyer and Lindauer\textsuperscript{25} showed that maxillary midline discrepancies of greater than 2 mm were likely to be noticed by laypeople, Kokich et al\textsuperscript{26} and Pinho et al\textsuperscript{27} found that laypeople didn’t even perceive 4 mm deviations. These studies were typically performed by altering photographs in certain increments and asking the subjects if the deviations were apparent.

A maxillary to mandibular midline discrepancy alters anterior esthetics and often determines how the posterior dentition will fit together\textsuperscript{28}. Esthetically, however, a small deviation of the mandibular midline from the maxillary midline will not cause any difficulties\textsuperscript{28}. In fact, the maxillary and mandibular midlines have been found to be non-coincidental in almost three fourths of the population\textsuperscript{20}. The PAR (Peer Assessment Rating) Index allows the mandibular midline to be up to one-quarter mandibular incisor width from the maxillary midline while still receiving the optimal score of 0\textsuperscript{29}. Nanda states that the alignment of the maxillary and mandibular dental midlines is less of an issue in esthetics because the visualization of the mandibular incisor midpoint is difficult due to their narrow width and uniform sizes\textsuperscript{30}. No previous studies have investigated the acceptability of maxillary to mandibular midline deviations.

The important relationship between the upper and lower anterior teeth is also expressed through overbite, which Proffit, Fields and Sarver characterize as ideal when
the value is between 0-2 mm\textsuperscript{28}. However, Iyer has shown that the mean incisor overbite was 3.2 mm in the population he studied, or approximately two-fifths coverage of the lower incisor\textsuperscript{31}. Although the mean incisor overbite was higher than the ideal, it has been shown that overbite can be treated orthodontically to within the normal ranges\textsuperscript{32}. In fact, many orthodontists feel they can orthodontically correct most deep overbite problems\textsuperscript{33}. In the PAR Index\textsuperscript{29}, the overbite is rated as normal when it is less than or equal to one third coverage of the lower incisor. No previous studies were found assessing the acceptability of increased or decreased overbite.

The vertical position of the lateral incisor affects the continuity of the smile arc and receives much attention in technique manuals\textsuperscript{34} in orthodontics. While it is widely claimed in the dental profession that a 0.5 mm step up in the lateral incisor is considered esthetic and natural, there is no literature available to corroborate that lay people desire this. Furthermore, conflicting evidence exists regarding the importance of canine guidance\textsuperscript{35}. During orthodontic treatment, formulaic bracket placement that is not supported by the literature should be avoided if it will not provide the final smile arc desired by patients.

Perfect bilateral symmetry in human beings is mostly a theoretical concept that seldom exists, and right-left differences are common in nature when two congruent but mirror image types are present\textsuperscript{36}. It has been found that asymmetry of the human face is the typical finding, even among esthetically pleasing faces. In fact, asymmetry seems to be a norm during animation of the face\textsuperscript{37}. Nevertheless, Kokich\textsuperscript{14} found a deviation in the transverse occlusal plane from the transverse (horizontal) axis\textsuperscript{38} to be an
overwhelmingly displeasing smile characteristic to health professionals and very noticeable to lay people. From a frontal view, a transverse occlusal cant may be caused by differential eruption of the maxillary anterior teeth or a skeletal asymmetry of the mandible\textsuperscript{7}. Occlusal cants are typically most apparent when a person smiles, and they cannot be seen on intraoral images or study casts\textsuperscript{21}. By altering the incisal plane around a central point at the incisal embrasure between the central incisor crowns, Kokich found that lay people were not able to detect incisal plane asymmetries until it was a 3-mm cant\textsuperscript{14}. This was found to be approximately equivalent to a 4° cant, given average smile width. Other studies have found that occlusal cant asymmetries are not noticeable until they are greater than 2°\textsuperscript{39}, 3°\textsuperscript{37} or 4°\textsuperscript{38}.

Gingival display while smiling is typically compatible with pleasing facial esthetics\textsuperscript{40}. In addition, the shape and contour of the gingiva are important to the final esthetic outcome of orthodontic patients\textsuperscript{41}. Crown length discrepancies are most common when one maxillary central incisor is shorter than the other, but the incisal edges are even. This discrepancy is often due to uneven gingival margins\textsuperscript{42} caused by uneven wear of one central incisor combined with passive incisor eruption. In a more recent study, Kokich et al found that laypersons could not detect asymmetric crown-length discrepancies of the maxillary central incisors until the crown was 1.5-2.0 mm shorter than its contralateral incisor\textsuperscript{43}. Pinho et al also found that laypersons could only notice changes that were equal to or greater than 2.0 mm\textsuperscript{27}. By manipulating the lateral incisor gingival margins, Kokich et al noted that gingival discrepancies between the maxillary central and lateral incisors were not noticeable\textsuperscript{14}. 

6
Kokich\textsuperscript{14} was the first to use computer based image modification in an attempt to quantify the acceptability of certain smile characteristics. It appears that he used life size smile images of the lips and teeth. Kokich only displayed female faces to reduce confounding variables. This method is supported as other authors\textsuperscript{44-46} have found no difference in esthetic ratings in male or female smiles.

Kokich found that orthodontists, general dentists, and lay people were able to detect discrepancies in smile characteristics at differing levels and that, for many variables, the lay people were less discriminating than the practitioners. A summary of his findings is below.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Orthodontists</th>
<th>General Dentists</th>
<th>Lay People</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crown length (mm)</td>
<td>1.0</td>
<td>1.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Crown width (mm)</td>
<td>3.0</td>
<td>3.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Incisor angulation (mm)</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Midline (mm)</td>
<td>4.0</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Open gingival embrasure (mm)</td>
<td>2.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Gingival margin (mm)</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Incisal plane (mm)</td>
<td>1.0</td>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Gingiva-to-lip distance (mm)</td>
<td>2.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

ND = nondetectable.

His study represented progress and opened new vistas for investigators, but was limited by excessive cropping of the lips and differences in skin tone, lipstick, tooth shape, and other distracters. Other authors\textsuperscript{45, 47} have advocated the inclusion of more facial features to allow the interaction between all smile related soft tissues and the dentition. Standardized images reduce confounding variables. Kokich also used
incremental adjustments of each variable for the raters to judge. This method of variable alteration might obscure the true threshold for variable awareness, depending upon the increment. It may be possible to refine and confirm the results of this study using more advanced digital imaging methods.

**STATEMENT OF THE PROBLEM**

More clarification as to what is ideal and acceptable in smile esthetics is necessary so that unique esthetic preferences can be incorporated for each patient\textsuperscript{48, 49}. This study will attempt to identify the ideal and acceptable range of several smile characteristics through digital image manipulation. The presentation of a standardized female circumoral area including the lower face will allow the smile to be seen in a more natural context. Smaller increments that appear to be nearly continuous will be incorporated. Most importantly, smile characteristics can be physically manipulated by the raters so they can appreciate the realm of possibilities before they choose what they find most appealing or at the threshold of acceptability. The definitive preferences of lay people for ideal and acceptable deviations of smile characteristics will be available from the data.
SPECIFIC AIMS

1. To develop and administer a computerized survey which displays standardized images of smiles for rating by adult subjects.

2. To evaluate the definitive preferences of lay people for ideal and acceptable deviations of smile characteristics among the following independent variables:

   a. Maxillary midline to face – The ideal maxillary midline to face is placed when the maxillary midline is coincident with the philtrum. The maxillary midline will be moved to the left of the face in 0.18 mm increments. The right and left buccal corridor will be maintained throughout the movement of the dentition. The ideal is defined for this variable.

   b. Maxillary to mandibular midline discrepancy – While maintaining the maxillary midline, the mandibular dentition will be moved to the left in 0.18 mm increments. The right and left buccal corridor will be maintained throughout the movement of the mandibular dentition. The ideal is defined for this variable.

   c. Overbite – The overbite, defined as the projection of the upper front teeth over the lower in the normal occlusal position of the jaws, will be modified by incrementally altering the mandibular layer of the photograph image in the vertical dimension. The vertical movement of the mandibular layer will produce an increased or decreased overbite. The layer is moved incrementally in 0.18 mm increments.
d. Crown width to length ratio – The maxillary central incisor, lateral incisor, and canine width to length ratio will be modified by altering the amount of gingiva covering the crowns of the aforementioned teeth. The length shall be modified in 0.18 mm increments. Because the width of the teeth will be maintained, the width to length ratio can then be calculated.

e. Central incisor gingival margin discrepancy – A common problem in orthodontic finishing is gingival margin discrepancies between contralateral incisors. In this study the gingival margin of the left maxillary central incisor will be altered in 0.18 mm increments. The incisal edges will be maintained at their original height.

f. Lateral Gingival Height Discrepancy – The difference in gingival heights between the maxillary central incisor and the maxillary lateral incisor will be assessed. The gingival margin of the left maxillary lateral incisor will be altered in 0.18 mm increments. The incisal edges will be maintained at their original heights.

g. Lateral Incisor Step – This variable will evaluate the difference between the incisal edges of the central and lateral incisors and will be assessed by moving the entire lateral incisor tooth up or down in 0.18 mm increments.

h. Lateral Incisor Size – The lateral incisor is the anterior tooth that most frequently presents with anomaly of size and shape. The most frequent anomaly is a “peg” shaped tooth where the height is grossly over
proportional in comparison to the width. The range of modification will be from normal to narrow in 0.18 mm increments.

i. Cant – The divergence of the occlusal plane from the horizontal axis, as seen in the smiling patient, will be altered by gradually rotating the plane through a point between the central incisors. The rotation of the plane will occur by 0.25° increments.

3. Investigate for regional differences in the above smile characteristics.

4. Prove the method is reliable.

**NULL HYPOTHESES**

\( H_01: \) Location of survey administration will not influence the perception of ideal and maximum acceptable values of esthetic and smile characteristics including the maxillary midline to face, maxillary to mandibular midline discrepancy, overbite, maxillary central incisor crown width to height ratio, maxillary central gingival levels, maxillary lateral gingival levels, maxillary central to lateral incisal edge discrepancy, maxillary lateral size discrepancy, and cant when evaluating digitally manipulated images of the smile and circumoral area.

\( H_02: \) Intra-rater preferences for ideal and maximum acceptable deviations will not be reliable.
References


CHAPTER 2
MATERIALS AND METHODS

This research presented to laypersons a comprehensive set of choices for numerous prominent smile characteristics so they could select the most ideal and maximum acceptable deviations of the characteristics. Digital “continuous” motion pictures of the possible values of smile characteristics (maxillary midline to face, maxillary to mandibular midline discrepancy, overbite, maxillary central incisor crown width to height ratio, maxillary central gingival levels, maxillary lateral gingival levels, maxillary central to lateral incisal edge discrepancy, maxillary lateral size discrepancy, and cant) using a gender ambiguous model were presented for the lay raters for evaluation.

Model Selection

The Ohio State University Section of Orthodontics digital archive was scanned for one intraoral center photograph of an ideally treated orthodontic case, and two extraoral photographs that displayed esthetic lips. Initial image selection and manipulation follows the protocol of Parekh, et al\textsuperscript{1}. The high resolution extraoral...
photographs were from one male and one female patient so that blending of the male image into the female image would represent no identifiable human being.

**Image Manipulation**

As in Parekh, et al\(^1\), original JPEG images were opened in Adobe Photoshop® CS2 and saved as a Photoshop® Document (PSD). This allowed for subsequent changes and saves to have similar resolution and quality. The intraoral center photograph was cropped to display only the right half of the mouth, and then mirrored for symmetry. The images of the face were cropped to show only the lips, nasal tip, and mentolabial fold with minimal other surrounding tissue. No other facial features were evident.

Using the imaging program, the teeth and periodontium were erased from the male and female lower face picture to create a “hollow” set of lips. Previous research has shown that there was no difference in lay person rating of the same smile in a male or female lip outline. Therefore, this study uses a female model. In order to create an unrecognizable face, a male lip profile was manipulated using the liquefy feature in Adobe Photoshop® CS2 at one-fourth opacity over the female lip profile so that the oral apertures were congruent. The male lip profile was then left at one-fourth opacity and merged with the female lip profile to make a composite of two faces into one unique and unidentifiable lower face and circumoral area.

Ideally, raters would see the smile and lower face as the same size on the computer screen when completing the survey as they would at typical conversational distance. The resolution was standardized on all computers used during this study at
1024 x 768 pixels. The teeth and lips were sized to meet these viewing dimensions. This was done through use of a digital measurement grid overlaid on the smile so that the central incisor width and height could be matched to the appropriate size. The lower face was then proportionally downsized from the original raw image to match the smile arc and buccal corridor quantity established as ideal by previous research.

Survey 2

Survey 2 focused on the following characteristics: maxillary midline to face, maxillary to mandibular midline discrepancy, overbite, maxillary central incisor crown width to height ratio, maxillary central gingival levels, maxillary lateral gingival levels, maxillary central to lateral incisal edge discrepancy, maxillary lateral size discrepancy, and cant, which will be discussed in the above order.

The ideal maxillary midline was determined by placing the middle of the embrasure between the maxillary central incisors onto a line determined to be the midline of the face. The maxillary dentition was then moved to the left in .18 millimeter increments through the use of the digital measurement tool in Photoshop™. This tool placed a grid over the image, allowing accurate movements in horizontal or vertical directions. In order to preserve a natural looking smile, the buccal corridor was maintained equally on both sides. This was done through the use of the liquefy function in Photoshop™. Careful morphing of the right and left posterior dentition allowed the buccal corridor to remain even. After moving the midline .18 millimeter and morphing the posterior dentition to maintain even buccal corridors, the lower face layer was placed
over the dentition, and this was saved as a separate image. The midline deviation ranged from 0 mm to 4.4 mm, with a total of 25 images. Each separate image was saved as layers in a separate Photoshop™ document which allowed them to be combined into a composite image.

The maxillary dentition was maintained when manipulating the maxillary to mandibular midline deviation variable. The mandibular midline was moved to the left in .18 millimeter increments to create this deviation. In order to move the mandibular dentition, the polygonal lasso tool in Photoshop™ was used to select the mandibular dentition, and it was then separated into a separate layer from the maxillary dentition. The clone stamp tool in Photoshop™ was then used to add enamel to the mandibular incisors to mimic the tooth portions missing due to the overbite in the 2-dimensional image. By using the grid, the mandibular dentition was then moved in equal .18 millimeter increments to the left. The liquefy function was then used to maintain normal overjet of the posterior dentition. After moving the mandibular midline .18 millimeter and morphing the posterior dentition to maintain normal posterior overjet, this was saved as a separate image. The maxillary to mandibular midline deviation ranged from 0 mm to 2.9 mm, with a total of 17 images. Each separate image was then saved as layers in a separate Photoshop™ document which allowed them to be combined into a composite image.

The overbite variable showed different amounts of overlap of the anterior dentition through movement of the mandibular anterior dentition. The polygonal lasso tool in Photoshop™ was used to select the mandibular dentition, and it was then
separated into a separate layer from the maxillary dentition. As previously described, enamel was added to the mandibular dentition to create normal mandibular incisors and canines. Incisal edges were carefully added to create natural-looking incisal edges. Starting from 0 mm overbite, the mandibular dentition was then moved vertically in .18 millimeter increments to mimic an increasing overbite. The liquefy function in Photoshop™ was used to move the posterior dentition down to maintain a normal posterior overbite, mimicking normal posterior tooth contacts. After moving the mandibular dentition .18 millimeter up and morphing the posterior dentition to maintain normal posterior tooth contacts, this was saved as a separate image. The overbite deviation ranged from 0 mm to 9.5 mm, with a total of 53 images. Each separate image was then saved as layers in a separate Photoshop™ document which allowed them to be combined into a composite image.

In order to calculate maximum deviations of overbite acceptable, two additional composite images were developed. One had a range from 0 mm to 2 mm, and the other had a range of 2 mm to 9.5 mm. By creating these two additional composites, we were able to have the subjects start at 2 mm overbite, then show what the last acceptable image would be, in either direction. The images were divided at 2 mm, which has been previously established as an ideal overbite.

Maxillary anterior crown heights were manipulated to change the crown width to height ratios of the maxillary centrals, laterals, and canines. The polygonal lasso tool in Photoshop™ was used to select the gingiva apical to the maxillary anterior dentition. The entire gingival segment, including the gingival embrasures, was selected. This
selected portion was cut and placed as a separate layer. Next, the clone stamp tool in Photoshop™ was used to increase the crown heights of the maxillary centrals, laterals, and canines. By overlaying the gingival layer over the maxillary dentition, the crown height of the maxillary anterior dentition could be altered. The crown height deviated from a minimum of 7.7 mm to a maximum of 14.6 mm, which allowed a range of crown heights beyond that which is anatomically normal. After moving the gingival layer .18 millimeter, this was saved as a separate image, with a total of 53 images. Each separate image was then saved as layers in a separate Photoshop™ document which allowed them to be combined into a composite image. A ratio was calculated between the width of the central incisor crown to the height of the central incisor crown to determine the ideal ratio.

Asymmetric gingival levels between the maxillary central incisors were manipulated using the polygonal lasso tool in Photoshop™. The gingiva apical to the maxillary left central incisor was selected using the lasso tool, and it was then copied and placed as a separate layer. This separate layer was then overlaid over the original image. Starting from ideal, this separate layer was moving in an incisal direction in .18 millimeter increments. The gingival levels deviated from a minimum of 0 mm to a maximum of 2.9 mm. After each movement, the image was saved as a separate image, with a total of 17 images. Each separate image was then saved as layers in a separate Photoshop™ document which allowed them to be combined into a composite image.

In order to assess the difference in gingival levels between the maxillary central and lateral incisors, the polygonal lasso tool in Photoshop™ was used to select the
gingiva apical to the lateral incisors only. This selected portion was cut and placed as a separate layer. Next, the clone stamp tool in Photoshop™ was used to increase the crown heights of the lateral incisors in an apical direction. By overlaying the lateral gingival layer over the dentition, the gingival level of the lateral incisors could be altered. The lateral gingival margin ranged from 3.8 mm incisal to the central gingival margin to 1.1 mm apical to the central gingival margin. Movements were made to the lateral gingival layer in vertical, .18 millimeter increments through use of the digital measurement tool and grid. After moving the lateral gingival layer .18 millimeter, the image was saved as a separate image, and this was done throughout the aforementioned range, for a total of 29 images. Each separate image was then saved as layers in a separate Photoshop™ document which allowed them to be combined into a composite image.

In order to calculate maximum deviations of acceptable lateral gingival margins, two additional composite images were developed, one ranging from 3.8 mm incisal to the central gingival margin to 1.3 mm incisal to the central gingival margin, and the other ranging from 1.3 mm incisal to the central gingival margin to 1.1 mm apical to the central gingival margin. By starting these two composite images at 1.3 mm incisal to the central gingival margin, we were able to find out the maximum acceptable deviations from the norm.

Incisal edge discrepancies between the maxillary central and lateral incisors were increased or decreased by the following method. The image used for the overbite variable was also used for alterations of this variable. The polygonal lasso tool in Photoshop™ was used to select and cut out the lateral incisor crowns, as well as the
gingiva apical to the crowns. This segment was then saved as a separate layer in the Photoshop™ document. By placing this layer over the initial layer of the dentition, the incisal edges of the maxillary lateral incisors were altered in a vertical direction.

Through use of the digital measurement grid, the lateral incisal edges were moved in .18 millimeter increments. Maximum deviations were saved, ranging from 0 mm (level with the central incisal edge) to 2.9 mm apical to the central incisal edge, for a total of 17 images.

The maxillary lateral incisors (“peg laterals”) were made wider and more narrow in order to assess their relationship with the central incisors. The polygonal lasso tool in Photoshop™ was used to select the distal half of the maxillary lateral incisor crown and the entire canine crowns, as well as the gingiva apical to those crowns. This selected portion was copied and placed as a separate layer. By moving this segment to the right or left, the apparent width of the peg laterals could be increased or decreased in .18 millimeter increments. After each movement, the Liquefy function was used to stretch the size of the first maxillary premolars to allow continuous contact with the canines. Deviations ranged from 1.1 mm larger than the ideal to 2.2 mm narrower than the ideal, with a total of 19 images. A ratio between the width of the maxillary lateral incisor to the width of the maxillary central incisor was calculated to assess the relationship between the lateral and central incisors.

An occlusal cant was created through use of the separate dental layer in Photoshop™. The Free Transform function in Photoshop™ was used to rotate the maxillary and mandibular dentition in .25 degree increments in a clockwise direction.
from a horizontal through the middle of the maxillary central incisors. After each rotation, the face was placed over the dentition, and this was saved as a new layer in the Photoshop™ document. The occlusal cant ranged from 0° to 6°, for a total of 25 images.

**Correction for Magnification**

A correction factor of .73 was needed in all variables using millimetric measurements due to magnification of the intraoral images in Photoshop™. Therefore, as reported above, each variable was altered in 0.18 mm increments instead of the planned .25 mm. All text and tables reflect the value for each smile characteristic after correction for magnification.

**Human Subjects Approval**

Applications for Institutional Review Board (IRB) exemption, HIPAA waiver, and Waiver of Written Informed Consent were made and granted by the Biomedical Sciences Institutional Review Board.

**Main Survey**

The survey was designed using the ideal and maximally deviant values for many smile characteristics studied in the previous studies of Parekh, et. al¹ and Kokich, et. al² as a guide, but allowing for increased variation. Two versions of the survey were necessary because inclusion of all variables in one survey would require too much time burden on the raters and possible fatigue.
Survey 1 and 2 were created using Quask Form Artist™ Professional Edition. Form Artist™ is survey administration software which allows questions to be linked to emoticons. Emoticons are a series of discrete pictures that represent the answer to a survey question. An example of an emoticon is the smiley face to frown with tears pain scale found in many doctor’s offices.

Emoticons were used in this study as a proxy for the display of fluid, continuously modifiable smiles over a pre-defined range. They were created by measuring the pixel width of the lower face image and multiplying that number of pixels by the number of morphed intraoral center pictures for each variable. This provided the appropriate size for the “comic strip” design for the emoticon layout. The morphed intraoral center image were coupled with the lower face image and laid out in sequential order along the “comic strip.” The comic strip was then compressed and saved as a Quask supported .gif image. Code was written in the emoticon notepad executable file telling the survey software what value each lower face-intraoral center combination image represented when selected by a rater.

Each emoticon was then joined to a slider bar which allowed the image to change as the slider was moved left/right or up/down. Due to the minute changes made during the initial image manipulation in Photoshop™, movement of the slider produced what appeared to be a continuous scale of possible smile choices even though changes were occurring in discrete .25 degree or .18 mm amounts.

The emoticons were then laid out in survey pages in Form Artist™ following several introductory slides. The survey began by detailing the purpose of the study,
followed by instructions, examples, and demographic questions used to typify the rater sample. Respondents were asked to voluntarily provide U.S. geographical region of residence, ethnic background, level of education completed, and dental affiliation. Any previous dental affiliation disqualified respondents from participation and terminated the survey so that the rater sample could be characterized as representative of the general population.

Upon completion of the introduction, respondents were launched into a series of 28 (Survey 1) or 26 (Survey 2) emoticon questions. Each emoticon question was presented with one of two statements: 1) “Please move the slider to select the image you find to be MOST IDEAL” or 2) “Please move the slider to select the first image that you find UNATTRACTIVE.” The first question was designed to clarify the ideal value for a given smile characteristic.

The second question was designed to elucidate how far in each possible direction from the median value a smile characteristic can deviate before becoming unattractive. For this research design, previously defined mean desirable values or values used in common clinical practice were set as the starting point when the emoticon was activated by the respondent. Any movement from this start point would theoretically be toward a less esthetic alternative and thus the maximum tolerable deviation in either direction of ideal for the aforementioned smile characteristics could be defined. The survey software presented the emoticons in random order for each rater to minimize bias.

Survey administration was completed in Seattle, WA, Columbus, OH, and Boston, MA by seeking anonymous participants over the age of 18. For the estimated
10-15 minutes of participation time, respondents received a ten dollar gift card. All surveys were presented on laptop computers with resolution set to 1024 x 768 so the aspect ratio was similar between all four computers. Wired optical mice were available at each computer. After survey administration was completed, rater responses were coded to a random number which linked all of the responses to a single rater. This information was then exported to a jump drive so the responses to each survey could be compiled for statistical analysis.

Statistical Analysis

Rater reliability was assessed for each variable as each emoticon question was presented twice inside Surveys 1 and 2 using the weighted Kappa statistic. Differences in attractiveness ratings were analyzed using descriptive statistics including median values. Multiple Mann-Whitney-Wilcoxon tests were conducted to investigate whether raters indicated different preferences for the smile characteristics by region. Due to the number of comparisons for the regional differences, a Bonferroni correction was instituted and adjusted p-values are reported. The level of significance was set at a p value of <0.05 for all analyses.

For an experiment-wise, non-directional alpha risk of 0.05 and assuming a common standard deviation of 17.42 a sample size of 100 subjects per rater group was necessary to achieve a power of 0.85 to demonstrate a difference of 1 mm or 1 degree on the slider scale.
References


CHAPTER 3

MANUSCRIPT:

Esthetics and Smile Characteristics from the Layperson’s Perspective: A Computer Based Survey Study

ABSTRACT

The paradigm shift from occlusion to esthetics emphasizes the interplay between dental structures and the surrounding soft tissue envelope. The objective of this study was to quantify the ideal and maximum acceptable deviation for nine smile characteristics by using digital manipulation of hard and soft tissue smile components. Intraoral photographs were manipulated using Adobe® Photoshop® CS2 to alter buccal corridor, smile arc, gingival display, crown torque in maxillary canines and the posterior buccal segments, maxillary midline to face, maxillary to mandibular midline, overbite, crown width to height ratio, central gingival height discrepancy, lateral incisor step, lateral incisor size, and maxillary cant. Smiles were placed in a lower face showing nasal tip to mentolabial fold. Quask™ Form Artist was used to generate the survey, which was administered in Columbus, OH (n=81); Seattle, WA (n=84) and Boston, MA (n=78). An interactive interface allowed raters to move a slider to answer questions. Rater reliability was assessed for each variable.
We found that, in general, raters were reliable ($K = 0.5-0.8$). Survey location was not significant except for the finding that the West coast accepted a broader smile (1.5 mm buccal corridor) than the Midwest and East coasts where the buccal corridor was found to be too minimal at 6 mm.

Rater preference for ideal and the threshold of acceptability is outlined below.

1. **SMILE ARC**: Considered ideal when the cusp tips of the maxillary 2\textsuperscript{nd} molars were 7.2 mm above the incisal edges of the maxillary central incisors. The acceptability range fell between 7.9 mm and 2.6 mm above the incisal edges.

2. **BUCCAL CORRIDOR**: 5.8 mm corridor on each side (16\%) considered ideal. The acceptability range was between 9.4 mm (26\%) and 2.9 mm (8\%) of corridor.

3. **GINGIVAL DISPLAY**: 2.1 mm (-2.1 mm gingival display) central incisor coverage by upper lip considered ideal. Acceptable range between 3.6 mm of gumminess and 4 mm of incisal coverage.

4. **CANINE TORQUE, IDEAL CORRIDOR**: -1 degree considered ideal with an acceptable range of +10 to -7 degrees.

5. **CANINE TORQUE, LARGE CORRIDOR**: -4 degrees considered ideal with an acceptable range of +8 to -10 degrees.

6. **POSTERIOR TORQUE, IDEAL CORRIDOR**: +4 degrees considered ideal with an acceptable range of +5 to -7 degrees.

7. **POSTERIOR TORQUE, LARGE CORRIDOR**: +6 degrees considered ideal with an acceptable range of +5 to -8 degrees.

8. **MAXILLARY MIDLINE TO FACE**: Acceptable range up to 2.9 mm deviation.
9. **MAXILLARY TO MANDIBULAR MIDLINE**: Acceptable range up to 2.1 mm deviation.

10. **OVERBITE**: 2.0 mm considered ideal with acceptable range of 0.4 mm to 5.7 mm.

11. **CROWN WIDTH TO HEIGHT RATIO**: Central incisor had ideal ratio of 0.73:1.

12. **CENTRAL GINGIVAL HEIGHT DISCREPANCY**: Acceptable up to 2.0 mm deviation.

13. **LATERAL GINGIVAL HEIGHT DISCREPANCY**: -0.4 mm considered ideal with acceptable range of -2.9 mm to 1.2 mm.

14. **LATERAL INCISOR STEP**: 1.4 mm considered ideal with acceptable range up to 2.9 mm.

15. **LATERAL INCISOR SIZE**: 0.72:1 considered ideal ratio with acceptable range of 0.53:1 to 0.76:1.

16. **CANT**: Acceptable up to 4.0° deviation.

We concluded that the preference of raters in different locations was not clinically significant and that raters displayed a wide range of acceptability for canine and posterior tooth crown torque in both narrow and broad smiles. This is a reliable method for determining individual smile characteristic preferences. Due to the wide range of acceptability for the ideal and threshold values for most variables, clinicians must be aware of individual preferences for each specific patient and should probably avoid sensitization of patients to smile characteristic deviations that fall within the acceptable range. The findings of this study can be used by clinicians as both a guideline toward ideal orthodontic finishes and acceptable compromise.
INTRODUCTION

The contemporary practice of dentistry must include management of the dentition and soft tissue to create an esthetic smile by tooth movement, soft tissue modification, restorative procedures, or some combination of these techniques. The development of an esthetic smile should be based on as much objective evidence as possible. Until recently, however, the refereed literature had not clarified the importance of smile characteristics. Studies in restorative dentistry and orthodontics demonstrated that dental professionals and laymen can identify smile characteristics that both enhance and detract from a smile.

Some studies have applied computer-based methodology to alter dental morphology and this appears to be an effective method to explore esthetics due to consistency of variable manipulation and controlled presentation.

Kokich Jr. was the first to use computer based image modification when he attempted to quantify smile characteristic acceptability using images of female lips and teeth. He found that orthodontists, general dentists, and lay people were able to detect discrepancies in smile characteristics and that, for many variables, lay people were less discriminating than the practitioners.

However, excessive cropping, skin tone differences, lipstick application, tooth shape, and other distracters can affect the perception of smile characteristics. Other authors have advocated the inclusion of more facial features to demonstrate the interaction between all smile related tissues. Further, large incremental adjustments (e.g. 1 mm) may have obscured the true threshold of acceptability. It may be possible to refine, confirm, and
expand the results of previous studies using more advanced digital imaging methods and survey presentation techniques.

A number of variables have been suggested to influence the attractiveness of a smile. Rosenstiel\textsuperscript{11, 12} suggested that the ideal width to height ratio for the maxillary anterior teeth is between 70 and 80\%. The ideal smile arc should mimic the curvature of the lower lip from central incisor to canine\textsuperscript{1, 14}. Buccal corridor minimization is a critical smile feature\textsuperscript{1, 6, 8, 15, 16}. Increased torque in posterior teeth is\textsuperscript{17, 18} a way to improve the esthetics of narrow smiles. Excessive gingival display does not appear to be well tolerated by raters\textsuperscript{2}. The highly variable permanent maxillary lateral incisor can be a challenging tooth to manage orthodontically and restoratively\textsuperscript{19}. Maxillary midline deviations can upset the balance of an otherwise esthetic smile\textsuperscript{20-22}. A maxillary to mandibular midline discrepancy alters anterior esthetics and indicates how posterior teeth will occlude\textsuperscript{23}. Overbite is generally characterized as ideal when the value is between 0-2 mm\textsuperscript{23}. The vertical position of the lateral incisor affects the continuity of the smile arc\textsuperscript{24}. Kokich\textsuperscript{2} found an occlusal plane cant to be an overwhelmingly displeasing smile characteristic to health professionals and lay people. The location, shape and contour of the gingiva in the maxillary anterior region affects smile esthetics\textsuperscript{25}. Clearly, there are numerous characteristics that make up a smile, but these must be disaggregated and systematically evaluated to determine their impact.

The purpose of this study was to definitively identify the ideal and acceptable range of several smile characteristics through presentation of a standardized gender ambiguous circumoral view including the lower face (a context that provided facial cues to symmetry) using raters from three regions of the U.S. Most importantly, smile characteristics were
manipulated by the raters on a visually continuous scale so they could appreciate the realm of possibilities before they chose what they found most appealing or at the threshold of acceptability.

MATERIALS AND METHODS

Model Selection and Image Manipulation

A university digital archive was examined for initial images following the protocol of Parekh, et. al\textsuperscript{1}. Adobe Photoshop® CS2 was used to crop the facial images to show only the lips, nasal tip, and mentolabial fold to reduce distractions. The teeth and periodontium were erased from the lower face to create a “hollow” lip set. An intraoral frontal photograph of an ideally treated dentition was used for all smile characteristic manipulation and was inserted inside the lip set after alteration.

These facial images were projected on the computer screen at a size comparable to typical conversational distance and resolution was standardized at 1024 x 768 pixels.

General Survey

The survey was designed to encompass a range of values for many smile characteristics. Two surveys were constructed to make the rater time requirement reasonable.

Survey 1 and 2 were created using Quask Form Artist\textsuperscript{™} Professional Edition, a survey administration software allowing questions to be linked to emoticons. Emoticons were used in this study to display continuously modifiable smiles over a pre-defined,
physiological range (Fig 3.1). The changes made during the initial image manipulation in Photoshop™ produced a visually continuous scale of possible choices when the slider bar coupled to the emoticon was manipulated (Fig 3.2).

The study was completed by 300 participants over age 18 with no dental affiliation. Voluntary response demographic questions, including gender, ethnicity, and socio-demographic status were gathered. Any previous professional dental affiliation disqualified respondents from participation and terminated the survey.

Raters evaluated 28 (survey 1) or 26 (survey 2) emoticon questions. Each emoticon question was randomly presented with one of two statements: 1) “Please move the slider to select the image you find to be MOST IDEAL” or 2) “Please move the slider to select the first image that you find UNATTRACTIVE.”

The survey was administered in Seattle, WA, Columbus, OH, and Boston, MA. Surveys were administered on identically configured laptop computers and all responses were anonymous.

**Survey 1 Content**

For all Survey 1 variables, the image manipulation is described below while the range of possible values and how the variable was measured is summarized in Table 3.1.

**Smile Arc**

The method of Parekh, et. al¹ was used to create a series of template parabolas to generate a nearly continuous set of possible smile arcs with Math GV™ FREEWARE Version 3.1.
**Buccal Corridor**

Buccal corridor spaces were manipulated by altering the amount of black space between the lip commissure and the most buccal tooth in the smile by moving the posterior teeth medially or laterally.

**Gingival Display**

Gingival display on smile was approached by modifying the skeletal position of the dental arches in .1825 mm increments.

**Crown Torque**

Individual tooth cutouts of the canine or all posterior teeth (1st premolar through second molar) were “torqued” positively or negatively through their center of rotation in a smile with an ideal (2% bilaterally\(^15\)) or wide buccal corridor. This method was chosen as the visibility of the posterior teeth may be different in broad and narrow smiles.

**Survey 2 Content**

For all Survey 2 variables the image manipulation and the range of possible values and how the variable was measured is summarized in Table 3.1.

**Maxillary Midline to Face**

The ideal maxillary midline was defined for the model and the maxillary dentition was moved to the left in .1825 mm increments while the posterior dentition was morphed to maintain even buccal corridors.
Maxillary to Mandibular Midline

With the maxillary dentition static, the mandibular midline was moved to the left in .1825 millimeter increments while normal posterior overjet was maintained.

Overbite

The amount of overlap of the anterior dentition was altered by moving the mandibular anterior dentition vertically in .1825 mm increments. Normal posterior tooth contacts were maintained.

Maxillary Central Incisor Crown Width to Height Ratio

Crown width to height ratios of the maxillary centrals, laterals, and canines were altered by moving an overlay gingival layer apically in .1825 millimeter increments. The width to height ratio was derived by dividing the maxillary central crown width by its corresponding height.

Maxillary Central Gingival Levels

Asymmetric gingival levels between the maxillary central incisors were created by moving the gingiva of the maxillary left central incisor incisally in .1825 millimeter increments.

Maxillary Lateral Gingival Levels

An overlay gingival layer allowed apical or incisal movement of the gingival zenith of the maxillary lateral incisors in .1825 millimeter increments.

Maxillary Central to Lateral Incisal Edge Discrepancy

The lateral incisors were moved in vertical, .1825 millimeter increments apically or incisally.
Maxillary Lateral Size Discrepancy

The widths of the maxillary lateral incisors were manipulated to be wider or narrower in .1825 millimeter increments using digitally dissected tooth cutouts. The posterior dentition was mesialized as needed to maintain tooth contacts.

Cant

The entire dentition was canted in one-quarter degree increments in a clockwise direction.

Statistical Analysis

Rater reliability was assessed for each variable using the weighted Kappa statistic. Differences in attractiveness ratings were analyzed using descriptive statistics including median and 95% confidence intervals. Multiple Mann-Whitney-Wilcoxon tests with Bonferroni correction of Holm were conducted to investigate for regional differences. The signed rank test was used to evaluate the possibility that raters prefer different amounts of crown torque in canines and posterior teeth when the size of the buccal corridor varies. The level of significance was set at $\alpha \leq 0.05$ for all analyses.

RESULTS

Rater Demographics

Because all individuals did not completely finish the survey, N=243 with 33% from each location – Boston, MA, Columbus, OH, and Seattle, WA. The final rater group was comprised of 66% female raters with a median education of Bachelors degree or higher and
income of $100-$150,000. 200 of 243 were Caucasian and the other 18% reported they were Asian, African American, Hispanic or other ethnicities.

Reliability

Weighted Kappa statistics are reported in Table 3.2.

Regional Effects on Rater Preference

Rater responses were sorted by region of residence in the United States. Multiple Mann-Whitney-Wilcoxon tests comparing west to east, west to central, and central to east indicate that the only significant finding was the preference for broader smiles (1.75 mm vs. 6 mm buccal corridor) by raters in the western group when compared to the central and eastern groups (p = .0252).

Effect of corridor size on torque preference

There was no difference in rater perception and preference of buccal crown torque in canines only or posterior teeth (Table 3.3).

Defining Ideal and Acceptable Smile Characteristics

The ideal (image) and the threshold of acceptability (image) are reported for each smile characteristic using medians. The summary statistics for the ideal smile characteristics are displayed in Figures 3 through 16.
DISCUSSION

The posed smile is repeatable and displays esthetic characteristics not visible during speaking and in repose. This makes the smile, aside from its social and psychological impact, an important facial state for investigation.

In this study, lay persons were surveyed because they are the primary consumer of orthodontic services. The possibility of regional differences (US: East, West and Midwest) had not been considered before and, ultimately, lay raters in different locations were not significantly different in assessment of individual smile characteristics. The penetration of mass media and popular culture may be responsible for this finding. The one difference, that raters on the west coast are more tolerant of a very broad smile, is probably not clinically significant.

It is still unclear how lay persons evaluate smile esthetics. There are many potential distracters and interactions between different smile characteristics. Numerous facial or dental characteristics can be distracters that supersede interpretation of smile characteristic deviation\textsuperscript{26}. Standardization of image presentation in a realistic context should allow for true assessment of lay rater preferences across numerous smile characteristics.

The observation that orthodontists flatten the smile arc\textsuperscript{27, 28} is less troubling given the findings of this study. Lay raters preferred a consonant smile but accepted a smile with minimal curvature as well (Figure 3.3). Parekh\textsuperscript{1} found flat smile arcs to be extremely objectionable but it appears that there are increments flatter than ideal that are acceptable. Interestingly, the addition of more upward curvature beyond what follows the lower lip did
not rate well. There is a wide and clinically significant difference between the upper and lower threshold but, generally, smiles should follow the curvature of the lower lip.

In order for the smile to follow the curvature of the lower lip, it is usually customary to increase the overbite. Our findings (Figure 3.4) suggest that lay raters are tolerant of a deep bite, which enables the creation of a congruent smile arc. Additionally, it is common orthodontic practice to incorporate a modest step between maxillary central and lateral incisors despite no evidence that this is a desirable technique. Our findings (Figure 3.5), support a lateral step up beyond the recommended value (0.5 mm) which allows establishment of a smile arc without excursive interferences. However, many raters preferred even incisal edges, emphasizing that individual preference should be assessed during finishing.

Previous reports of ideal buccal corridor size vary from 2%\textsuperscript{6} to 19%\textsuperscript{29}. Our ideal corridor size (Figure 3.6) was 16% and our acceptability range (8-26%). It appears that raters prefer the appearance of a buccal corridor approaching the 19% reported from untreated patients. Facial perspective or inclusion of more than the circumoral area, however, may make a difference.

Buccal corridor ratings indicate that visualization of the buccal segments may have an esthetic impact. Crown torque in the posterior segments may be visible but claims that increased torque improves the esthetics of a narrow smile\textsuperscript{17, 18} have not been substantiated. In our study, lay persons tolerated nearly every image presented to them and unexpectedly preferred negative torque in narrow smiles (Figures 3.7a through 3.8b). Torque of canines and posterior teeth should probably only be controlled for functional occlusion purposes.
Gingival display has been investigated extensively\textsuperscript{2, 13, 27, 29-36}. Kokich Jr.\textsuperscript{2} first reported 4 mm of gingival display represented the threshold of acceptability but recently\textsuperscript{13} used smaller increments found it to be 3 mm. Our data (Figure 3.9) found the ideal value for gingival display to be 2.1 mm incisor coverage and the acceptable range was essentially \(\pm 4\). Vertical lip changes occur with aging\textsuperscript{37-41} and may make maintenance of gingival display difficult, but, finishing within the acceptability range should be possible.

The location, shape, and contour of the maxillary anterior gingiva are important smile characteristics\textsuperscript{25}, especially in the context of a smile with some amount of gingival display. Crown length discrepancies are most common when one maxillary central incisor is shorter than the contralateral incisor\textsuperscript{42} due to uneven wear of one central incisor combined with active incisor eruption. Recent investigators\textsuperscript{13, 43} found that laypersons did not detect asymmetric crown-length unless one crown was 1.5-2.0 mm shorter than the other. Our study (Figure 3.10) verified that 2.0 mm is the limit of acceptability for this variable. It is interesting to note, however, that a third of the raters did not find the discrepancy to be unacceptable until the heights had a 4.0 mm difference.

Kokich et al noted that gingival discrepancies between the maxillary central and lateral incisors were not obvious to lay persons\textsuperscript{2}. Our study confirmed (Figure 3.11) the broad range of acceptability for this variable and demonstrated it was even acceptable when the lateral gingival margin was superior to the central gingival margin.

Kokich\textsuperscript{2} also found that lay people needed a 2-mm deviation of the ideal crown length in order to classify the central incisors as noticeably less esthetic. In his research, Kokich defined the ideal central incisor crown width to height ratio at approximately
0.77, and the 2-mm deviation resulted in a width to height ratio of approximately 0.90. In a study reviewing anatomic crown width/length ratios, Magne \(^{44}\) found that unworn central incisors had a ratio of 0.78. Other studies have shown similar values \(^{4, 12, 45}\). Our findings (Figure 3.12) confirmed these values.

Proportional size of the maxillary lateral incisor is interesting due to the variability in size of this tooth. The most frequent anomaly is a “peg” shaped tooth where the width is grossly decreased in comparison to the height. Kokich Jr. found that the threshold for acceptability was 4.0 mm narrower than the ideal lateral incisor \(^2\). At the ideal, the lateral incisor was 78\% of central incisor width, while at the threshold it was 45\%. Our findings (Figure 3.13) were similar at 72\% for ideal and a threshold value of 53\%. Lateral incisors can be as wide as 76\% of the central incisor before becoming unacceptable.

The maxillary dental midline is often compared to the facial midline using the center of the philtrum \(^{33, 46-48}\) and soft tissue nasion \(^{33, 48}\). Numerous authors \(^{49-52}\) have demonstrated that maxillary midline discrepancies >2 mm were likely to be noticed by laypeople, while others \(^2, 43\) found that laypeople could not perceive a 4 mm deviation. Our findings (Figure 3.14) established the maximum acceptable value to be 3.0 mm although one third of our respondents accepted a deviation of 4.3 mm.

Maxillary and mandibular midlines are non-coincident in three-fourths of the population \(^{46}\) and small deviations will not cause any detriment to smile esthetics \(^{23}\). The contribution of mandibular midline to esthetics may be diminished due to the narrow width and uniform size of mandibular incisors \(^{53}\). We found that (Figure 3.15) mandibular
midline deviation was acceptable until it exceeded 2.1 mm and one third of the respondents accepted the maximal deviation of 2.9 mm. This demonstrates that many individuals found this deviation to be acceptable when over half the mandibular incisor deviated from the maxillary midline. This adequately accommodates patients with a missing or extracted lower incisor.

Asymmetry, even among esthetically pleasing faces, is a typical finding. An occlusal cant is a form of asymmetry apparent when a person smiles that is not seen on intraoral images or study casts. Kokich Jr. found that lay people did not detect this type of asymmetry until it reached 3-mm (equivalent to 4°). Other studies have found they are not noticeable unless they are exceed 2°, 3° or 4°. We found (Figure 3.16) that lay people accepted cants until they reached 4°, but one-third of the respondents accepted cants at the maximum deviation of 6°.

This method provided a means to accurately and reliably identify the ideal value for many smile characteristics. Some values deviated from previous findings while others were confirmed. Yet, the issue with the existing literature on this topic remains variability, which makes comparison of results cumbersome. Other smile characteristics were investigated here for the first time (torque preference, overbite, maxillary to mandibular midline deviation, lateral incisor step, and lateral gingival margin height). The sum of the findings provides an outline for clinicians to assemble patient centered orthodontic, restorative and periodontal results.

Probably, the most important finding is the range of acceptability. Lay raters tolerated a wide range of variability for most characteristics and knowledge of what is ideal
does not make it appropriate to ignore this range. It is probably sound for the clinician to use care in identifying the ideal to patients when that knowledge could sensitize them to unrealistic or unattainable goals. In their naiveté they are more inclusive than practitioners would think. Remembering that our values as clinicians should not be imposed except near the margins of acceptability is probably the best guide.

Limitations and Future Directions

Our study only provided rater preference in the context of the lower face including the mentolabial fold and the nasal tip. Other studies have displayed fewer facial features and found different results than those reported here. It is clear that the context in which the smile is presented may make a difference to raters and this must be considered in future research of this type. Additionally, demographic sampling was not controlled. While age and gender have previously shown no effect on smile characteristic ratings, ethnicity and cultural background may make a difference. This could be considered in future investigations as well.

CONCLUSIONS

1. In the assessment of individual smile characteristics, the difference of raters for different locations was not clinically significant, although there was one statistically significant finding (wider smiles more tolerable to West versus Midwest and East).

2. There is no significant difference in the perception of ideal and acceptable values of posterior and canine torque in narrow and broad smiles.
3. This is a reliable method for determining individual smile characteristic preferences.

4. Due to the wide range of acceptability for ideal and the overall range of acceptability for most variables, clinicians must be aware of individual preferences for each specific patient.

5. The findings of this study can be used by clinicians as both a guideline toward ideal orthodontic finishes and acceptable compromises.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Range of Values</th>
<th>How Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Smile Arc</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At maxillary Canine</td>
<td>0 mm - 2.4 mm</td>
<td>Vertical distance from horizontal tangent from maxillary central incisors to cusp tip of maxillary canine or 2nd molar</td>
</tr>
<tr>
<td>At maxillary 2nd Molar</td>
<td>0 mm - 6.6 mm</td>
<td></td>
</tr>
<tr>
<td><strong>Buccal Corridor (bilateral total)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Millimetric</td>
<td>0 - 10.2 mm</td>
<td>Horizontal distance from the facial of the most buccal posterior tooth to a vertical line through the commisure of the lips</td>
</tr>
<tr>
<td>Percentage</td>
<td>0 - 22%</td>
<td></td>
</tr>
<tr>
<td><strong>Gingival Display</strong></td>
<td>-5.1 mm to +5.8 mm</td>
<td>Amount of positive or negative lip amount from the gingival zenith of the maxillary central incisors to the nadir of the upper lip above these teeth</td>
</tr>
<tr>
<td><strong>Canine Torque, Broad Smile</strong></td>
<td>-10 to +10 degrees</td>
<td>Amount of positive or negative torque in the bilateral maxillary canine teeth rotated through the center of rotation for each tooth</td>
</tr>
<tr>
<td><strong>Canine Torque, Narrow Smile</strong></td>
<td>-10 to +10 degrees</td>
<td>Amount of positive or negative torque in the bilateral maxillary canine teeth rotated through the center of rotation for each tooth</td>
</tr>
<tr>
<td><strong>Posterior Torque, Broad Smile</strong></td>
<td>-10 to +10 degrees</td>
<td>Amount of positive or negative torque in the bilateral maxillary posterior teeth (1st premolar through 2nd molar) rotated through the center of rotation for each tooth</td>
</tr>
<tr>
<td><strong>Posterior Torque, Narrow Smile</strong></td>
<td>-10 to +10 degrees</td>
<td>Amount of positive or negative torque in the bilateral maxillary posterior teeth (1st premolar through 2nd molar) rotated through the center of rotation for each tooth</td>
</tr>
<tr>
<td><strong>Maxillary Midline to Face</strong></td>
<td>0 mm - 4.4 mm</td>
<td>Horizontal distance from the middle of the embrasure between the maxillary central incisors onto a line determined to be the midline of the face</td>
</tr>
<tr>
<td><strong>Maxillary to Mandibular Midline</strong></td>
<td>0 mm - 2.9 mm</td>
<td>Horizontal distance between the middle of the embrasure of the maxillary central incisors to the middle of the embrasure between the mandibular central incisors</td>
</tr>
<tr>
<td><strong>Overbite</strong></td>
<td>0 mm - 9.5 mm</td>
<td>Vertical distance from the maxillary central incisal edge to the mandibular central incisal edge</td>
</tr>
</tbody>
</table>

Table 3.1: Variable Summary  

Continued
<table>
<thead>
<tr>
<th>Variable</th>
<th>Range of Values</th>
<th>How Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Gingival Height</td>
<td>0 mm - 2.9 mm</td>
<td>Vertical distance between the apex of the right maxillary central incisor</td>
</tr>
<tr>
<td>Discrepancy</td>
<td></td>
<td>gingival margin to the apex of the left maxillary central incisor gingival</td>
</tr>
<tr>
<td></td>
<td></td>
<td>margin</td>
</tr>
<tr>
<td>Lateral Gingival Height</td>
<td>1.1 mm apical</td>
<td>Vertical distance between the apex of the maxillary central incisor gingival</td>
</tr>
<tr>
<td>Discrepancy</td>
<td>to central</td>
<td>gingival margin to the apex of the maxillary lateral incisor gingival</td>
</tr>
<tr>
<td></td>
<td>incisor - 3.8</td>
<td>margin</td>
</tr>
<tr>
<td></td>
<td>mm incisal to</td>
<td></td>
</tr>
<tr>
<td></td>
<td>central incisor</td>
<td></td>
</tr>
<tr>
<td>Lateral Incisor Step</td>
<td>0 mm - 2.9 mm</td>
<td>Vertical distance between the maxillary central incisor edge to the maxillary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>lateral incisor edge</td>
</tr>
<tr>
<td>Lateral Incisor Size</td>
<td>0.53:1 - 0.76:1</td>
<td>Ratio between the width of the maxillary lateral incisor to the width of the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>maxillary central incisor</td>
</tr>
<tr>
<td>Cant</td>
<td>0 to 6 degrees</td>
<td>Amount of rotation in the maxillary and mandibular dentition from horizontal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>through the middle of the maxillary central incisors</td>
</tr>
<tr>
<td>Smile Characteristic Rated</td>
<td>Value</td>
<td>LCB (95%)</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>-------</td>
<td>-----------</td>
</tr>
<tr>
<td>Smile Arc</td>
<td>0.79</td>
<td>0.74</td>
</tr>
<tr>
<td>Buccal Corridor</td>
<td>0.81</td>
<td>0.76</td>
</tr>
<tr>
<td>Gingival Display</td>
<td>0.87</td>
<td>0.84</td>
</tr>
<tr>
<td>Canine Torque, Broad Smile</td>
<td>0.71</td>
<td>0.65</td>
</tr>
<tr>
<td>Canine Torque, Narrow Smile</td>
<td>0.70</td>
<td>0.64</td>
</tr>
<tr>
<td>Posterior Torque, Broad Smile</td>
<td>0.72</td>
<td>0.67</td>
</tr>
<tr>
<td>Posterior Torque, Narrow Smile</td>
<td>0.74</td>
<td>0.68</td>
</tr>
<tr>
<td>Maxillary Midline to Face</td>
<td>0.71</td>
<td>0.57</td>
</tr>
<tr>
<td>Maxillary to Mandibular Midline</td>
<td>0.56</td>
<td>0.40</td>
</tr>
<tr>
<td>Overbite</td>
<td>0.88</td>
<td>0.83</td>
</tr>
<tr>
<td>Crown Width to Height Ratio</td>
<td>0.34</td>
<td>0.13</td>
</tr>
<tr>
<td>Central Incisor Gingiva</td>
<td>0.70</td>
<td>0.55</td>
</tr>
<tr>
<td>Lateral Incisor Gingiva</td>
<td>0.81</td>
<td>0.77</td>
</tr>
<tr>
<td>Lateral Incisor Step</td>
<td>0.47</td>
<td>0.34</td>
</tr>
<tr>
<td>Lateral Incisor Size</td>
<td>0.73</td>
<td>0.67</td>
</tr>
<tr>
<td>Cant</td>
<td>0.76</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Table 3.2: Weighted Kappa for Reliability
<table>
<thead>
<tr>
<th>Variable</th>
<th>Narrow Smile Median Value</th>
<th>Broad Smile Median Value</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Canine Torque</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ideal</td>
<td>- 4 degrees</td>
<td>- 1 degree</td>
<td>3 degrees***</td>
</tr>
<tr>
<td>Maximum</td>
<td>+ 8 degrees</td>
<td>+ 10 degrees</td>
<td>2 degrees</td>
</tr>
<tr>
<td>Minimum</td>
<td>- 10 degrees</td>
<td>- 7 degrees</td>
<td>3 degrees***</td>
</tr>
<tr>
<td><strong>Posterior Torque</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ideal</td>
<td>+ 6 degrees</td>
<td>+ 4 degrees</td>
<td>2 degrees*</td>
</tr>
<tr>
<td>Maximum</td>
<td>+ 5 degrees</td>
<td>+ 5 degrees</td>
<td>ND</td>
</tr>
<tr>
<td>Minimum</td>
<td>- 8 degrees</td>
<td>- 7 degrees</td>
<td>1 degree</td>
</tr>
</tbody>
</table>

* p < .05  
** p < .001  
*** p < .0001

Table 3.3: Signed Rank for Torque Difference
Figure 3.1: Emoticon Example
Click on the picture to activate the slider.

Use the slider to select the picture you find most ideal.
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>7.9 mm at 7s 4.4 mm at 3s</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>7.2 mm at 7s 4 mm at 3s</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>2.6 mm at 7s 2.1 mm at 3s</td>
</tr>
</tbody>
</table>

Figure 3.3: Smile Arc
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>5.7 mm</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>2.0 mm</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>0.4 mm</td>
</tr>
</tbody>
</table>

*Figure 3.4: Overbite*
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
<th>2.9 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ideal</td>
<td>1.4 mm</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3.5: Lateral Step Up
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td>2.9 mm (8%)</td>
<td></td>
</tr>
<tr>
<td>Ideal Value</td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>5.8 mm (16%)</td>
<td></td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>9.4 mm (26%)</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3.6: Buccal Corridor
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>+10 degrees</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>-1 degrees</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>-7 degrees</td>
</tr>
</tbody>
</table>

Figure 3.7a: Canine Torque in a Broad Smile
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>+8 degrees</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>-4 degrees</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>-10 degrees</td>
</tr>
</tbody>
</table>

Figure 3.7b: Canine Torque in a Narrow Corridor
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>+5 degrees</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>+4 degrees</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>-7 degrees</td>
</tr>
</tbody>
</table>

Figure 3.8a: Posterior Torque in a Broad Smile
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>+5 degrees</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>+6 degrees</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>-10 degrees</td>
</tr>
</tbody>
</table>

*Figure 3.8b: Posterior Torque in a Narrow Smile*
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>-3.6 mm</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>2.1 mm</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>4 mm</td>
</tr>
</tbody>
</table>

Figure 3.9: Gingival Display
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>2.0 mm</td>
</tr>
<tr>
<td>Ideal</td>
<td>0 mm</td>
</tr>
</tbody>
</table>

Figure 3.10: Central Gingival Height Discrepancy
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>1.2 mm</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>-0.4 mm</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>2.9 mm</td>
</tr>
</tbody>
</table>

Figure 3.11: Lateral Gingival Height Discrepancy
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ideal</td>
<td>.73 (Width/Height)</td>
</tr>
</tbody>
</table>

Figure 3.12: Crown Width to Height Ratio
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>0.76:1</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>0.72:1</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>0.53:1</td>
</tr>
</tbody>
</table>

Figure 3.13: Lateral Incisor Size
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>2.9 mm</td>
</tr>
<tr>
<td>Ideal</td>
<td>0 mm</td>
</tr>
</tbody>
</table>

Figure 3.14: Maxillary Midline to Face
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>2.1 mm</td>
</tr>
<tr>
<td>Ideal</td>
<td>0 mm</td>
</tr>
</tbody>
</table>

Figure 3.15: Maxillary to Mandibular Midline
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>4 degrees</td>
</tr>
<tr>
<td>Ideal</td>
<td>0 mm</td>
</tr>
</tbody>
</table>

Figure 3.16: Occlusal Cant


1. In the assessment of individual smile characteristics, there were no clinically significant difference between raters at different US locations.

2. Using emoticon technology is a reliable method for determining individual smile characteristic preferences.

3. Due to the wide range of acceptability for most variables, clinicians must be aware of individual preferences for each specific patient.

4. The findings of this study can be used by clinicians as both a guideline toward ideal orthodontic finishes and acceptable compromises.
BIBLIOGRAPHY


Angle, E. H. Malocclusion of the Teeth and Fractures of the Maxillae.


